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Article Addendum

Plants Respond to GSM-Like Radiation

Alain Vian[1]*
Catherine Faure[1]
Sébastien Girard[2]
Eric Davies[3]
Francis Hallé[4]
Pierre Bonnet[2]
Gérard Ledoigt[1]
Françoise Paladian[2]

[1]Departement de Biologie Physiologie et Genetique Vegetales–EA-3296 ERTAC; [2]UMR CNRS 6602 LASMEA; Université Blaise Pascal; Aubière, France

[3]Department of Plant Biology; North Carolina State University; Raleigh, North Carolina USA

[4]Université Montpellier 2; Montpellier, France

*Correspondence to: Alain Vian; Physiologie et Génétique Vegetales—ERTAC; Université Blaise Pascal; Campus des Cezeaux; Aubiere, 63177 France; Tel.: +33.473.407.918; Fax: +33.473.407.942; Email: alain.vian@univ-bpclermont.fr

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Addendum to:

Intercellular Communication in Plants: Evidence For Two Rapidly-Transmitted Systemic Signals Generated in Response to EMF Stimulation in Tomato

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ABSTRACT

In this article, we propose that an organism's general architecture is of primary importance for its ability to perceive electromagnetic radiation. Animals develop mainly as volumes for internal assimilation and appendages to increase their mobility, while plants develop as surfaces to optimize interaction with the environment. As a consequence, the proportion of cells directly interacting with EMF radiation at the organism/environment interface is much higher in plants than it is in animals, making them especially suited to study EMF effects on life.

STUDYING EMF EFFECTS ON LIFE

What is needed to establish a direct relationship between EMF exposure and a biological response? Pre-requisites for such studies are: (1) a facility where the urban EMF environment can be both excluded and mimicked; (2) an organism exquisitely sensitive to EMF; (3) a response sufficiently simple and rapid that it is a direct consequence of EMF exposure.

HOW CAN AN URBAN EMF ENVIRONMENT BE BOTH EXCLUDED AND MIMICKED?

We have designed and constructed a highly specialized and complex facility, the mode-stirred reverberation chamber (MSRC) which excludes environmental EMF while simultaneously generating EMF whose characteristics closely mimic those present in the urban environment.[1] It consists of a large, metal-walled room (8.4 x 6.7 x 3.5 m, about 195 m^3) that acts as a Faraday cage (Fig. 1), thus protecting the experiment from external EMF, along with a tunable EMF antenna. The EMF generated by this antenna are then reflected onto the walls, randomly scattered by the rotation of a large stirrer which continuously changes the spatial electromagnetic field distribution, and makes it statistically homogeneous and isotropic. These characteristics are those found in urban environments, where multiple reflections and diffractions of EMF from buildings, mountains and trees are observed. This facility has proven to be extremely well suited for bio-electromagnetism studies.[2-4]

WHY DO PLANTS MAKE SUCH OUTSTANDING MODEL SYSTEMS FOR EMF STUDIES?

Plants have several advantages over animals for studying EMF effects on life such as their immobility, their sensitivity to even minute changes of their environment and their lack of a psychological stress response. Despite these advantages, plants have been used in only a limited number of reports.[5-8] These advantages derive primarily from their mechanisms for assimilation of materials and energy. In contrast to animals, which absorb and release materials through interior tubes thus minimizing their surface/volume ratio (SVR), plants maximize their SVR to optimize water and mineral uptake (roots) as well as gas exchange and light absorption (leaves).[9] This fundamental difference is of primary importance, since it greatly affects the proportion of cells situated at the organism/ EMF interface, ensuring that plants have a high proportion of cells which directly interact with the electromagnetic wave, and many of which (leaf cells) are specially adapted to absorb EMF in the visible spectrum. As an example, 1 cm^3 of animal tissue has a surface area of 6 cm^2, while for the same volume, a 0.5 mm-tick leaf would have a 41 cm^2 surface area, i.e., almost seven times as much (Fig. 2).

WHICH RESPONSES ARE THE BEST TYPES TO MEASURE?

Much earlier EMF research has focused on long-term psychological responses in humans, which give, at best, a highly indirect connection between EMF and the biological response.[10] In contrast we have chosen to study rapid, molecular responses in plants to establish direct connections.[2] These have involve monitoring the levels of several wound-induced transcripts within minutes after short-term EMF exposure to tomato plants. Data from several experiments are summarized in Table 1, which highlights two major findings. The first is that all the transcripts we have shown to be upregulated had previously been found to be wound-induced, implying that tomato pants perceive and respond to low (cell-phone level) EMF as though it were injurious. The second is that the response

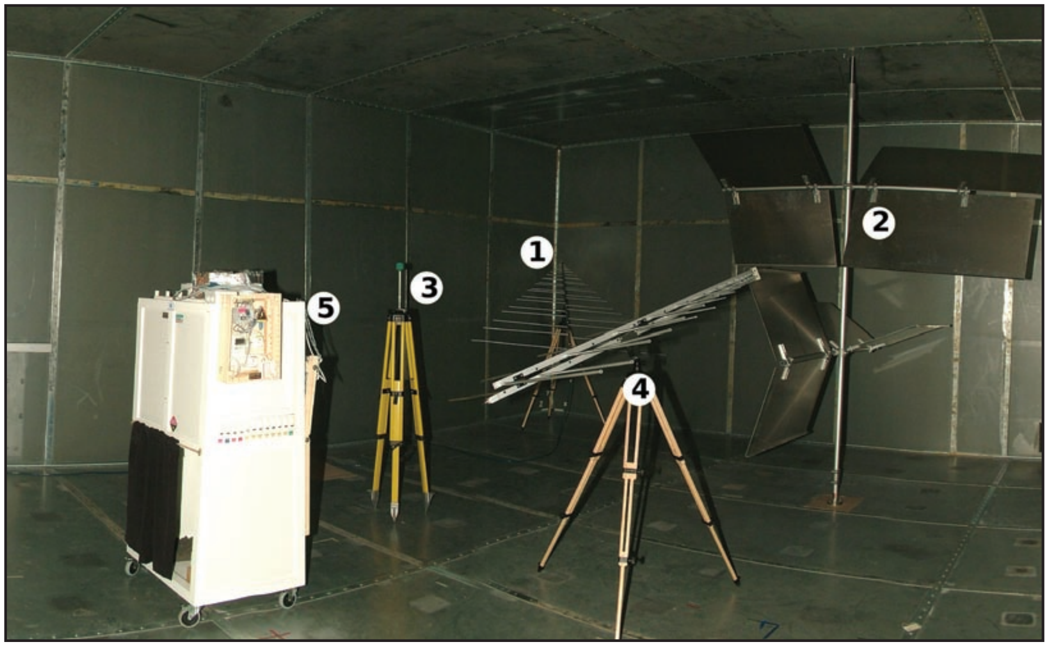

Figure 1. EMF exposure facility (Mode Stirred Reverberating Chamber). The MSRC is a large metal-walled room, which acts as a Faraday cage. The emission antenna (1) emits an electromagnetic wave that reflects onto the walls of the chamber, the rotation of the stirrer (2) continuously changes its geometry, making the electromagnetic field isotropic and homogeneous. The field characteristics are measured using a PMM-183 electric probe (3), and a log-periodic antenna (4). The plants are cultivated in a specialized, EMF-permeable culture chamber (5) placed in the working volume where the field characteristics are certified accordingly to the IEC 61000-4-21 specifications.

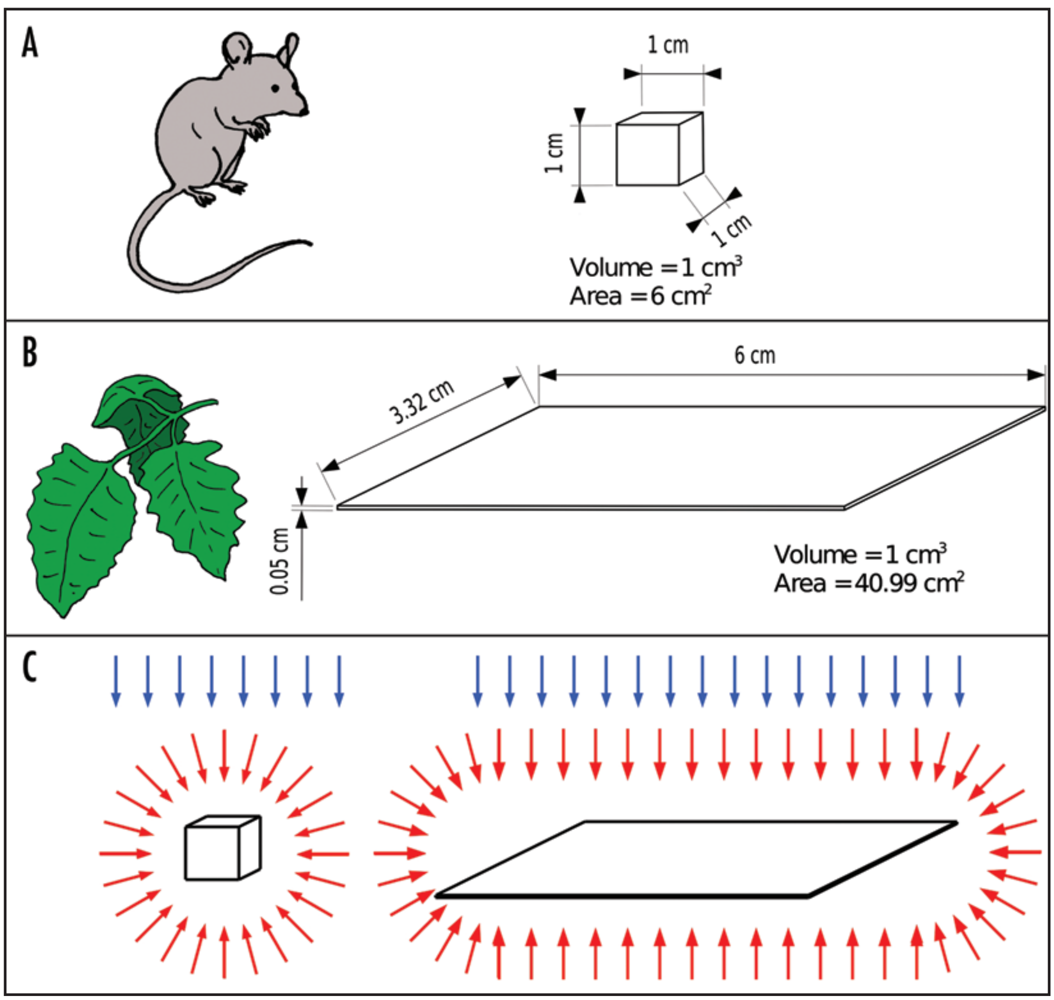

Figure 2. Plants versus animals: differences in their body architectures. (A) Animals develops more as volumes for internal assimilation with appendages to promote mobility, thus an extremely low proportion of cells are localized at the animal/environment interface, thereby minimizing their surface area for detecting external factors. A 1 cm^3 volume has linear dimensions of 1 cm, thus the total surface area is 6 cm^2. The proportion of cells at the animal/wave interface is low, even when an isotropic and homogeneous field is used (red arrows). (B) Plants develop essentially as surfaces to optimize interaction with their environment. As a consequence, a high proportion of cells are at the plant/environment interface, facilitating the detection of external factors. Plants develop as surfaces. For the same 1 cm^3 volume, a 0.05 cm thick plant leaf would be 6 x 3.32 cm, leading to a surface area of 41 cm^2 (about 6.8-times as much as animals). The proportion of cells at the plant/EMF interface is high, particularly when an isotropic and homogeneous field is used (red arrows). (C) In both cases, EMF of fixed incidence angle and polarization (blue arrows) illuminate the organisms much less efficiently than does an isotropic homogeneous field (red arrow) that displays every field incidence and polarization.

Table 1 **Table summarizing the responses (accumulation of stress-related transcripts) after 900 Mhz electromagnetic stimulation of different amplitudes and durations**

Duration	Amplitude	Transcripts	Response	References
1 min	5 Vm^{-1}	bZIP	NO	unpublished
2 min	5 Vm^{-1}	CaM, CMBP, PIN2	NO	2,3,4
10 min	0.5 Vm^{-1}	bZIP	NO	2.4
10 min	5 Vm^{-1}	bZIP, CaM, CMBP, PIN2	YES	2,3,4
10 min	40 Vm^{-1}	CaM, CMBP, PIN2	YES	3

appears to be "all-or-none", the intensity of the response observed after a 40 Vm^{-1} stimulation being comparable to the one evoked by a 5 Vm^{-1} [3]. This "all-or-none" response, along with the fact that responses are systemic, i.e., they occur very rapidly in a protected leaf after exposing a distant leaf to EMF,[4] strongly suggest that the EMF-evoked "wound" signal is an electrical signal, the action potential.[11]

ARE THESE FINDINGS RELEVANT TO MAN?

The rapid responses of plants to EMF stimulation are unlikely to be directly transferable to man or other animals, since the organism's general architecture may be a critical parameter for EMF to be perceived, and thus for a response to occur. However, we are currently conducting experiments with human cultivated keratinocytes, which develop as a thin, spreading cell monolayer and thus have a general architecture similar to that of plant leaves. This research will be accomplished through a grant from the MAPHYS research project supported by the French Foundation for Health and Radio-Frequencies (Fondation Santé et Radiofréquences).

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